The European Journal of Plant Science and Biotechnology ©2009 Global Science Books

Antioxidative and Anti-glycation Activity of Bitter Buckwheat Tea

Danuta Zielińska[1*] • Dorota Szawara-Nowak[2] • Henryk Zieliński[2]

[1] University of Warmia and Mazury in Olsztyn, Plac Lodzki 4, 10-957 Olsztyn, Poland
[2] Institute of Animal Reproduction and Food Research of Polish Academy of Sciences, Tuwima 10, P.O. Box 55, 10-747 Olsztyn, Poland
Corresponding author: * **dziel@uwm.edu.pl**

ABSTRACT

Unhusked tartary buckwheat and green tea with mint leaves were used for the preparation of ready-to-drink bitter buckwheat tea and green tea with mint. An 80% methanol extract of dry unhusked tartary buckwheat and bitter buckwheat tea were characterized for total phenolic contents (TPC), flavonoids profile, DPPH radical scavenging activity (DPPH RSA) and antioxidative capacity by the cyclic voltammetry (CV) assay, whilst the anti-glycation activity of bitter buckwheat tea was evaluated *in vitro* in a bovine serum albumin (BSA)-glucose model. The antioxidative and anti-glycation activities of bitter buckwheat tea were compared to those of green tea with mint. The dry unhusked tartary buckwheat showed 5 times lower TPC content when compared to that of green tea leaves with mint. The analysis of flavonoids in dry unhusked tartary buckwheat showed a high content of rutin followed by a moderate level of quercetin and low contents of flavone *C*-glucosides. Rutin was the main bitter buckwheat tea flavonoid, while quercetin was not detected. The bitter buckwheat tea showed about 5 times lower antioxidative capacity determined with DPPH RSA (5 times) and with the CV assay (two-fold) than green tea with mint. The ready-to-drink bitter buckwheat tea showed 69% inhibition of the formation of AGEs, whereas that noted for green tea with mint reached 98%. Therefore, unhusked tartary buckwheat may be used for tea preparation as the main single tea ingredient or as a mixed component of other tisanes.

Keywords: total phenolics, flavonoids profile, antioxidative capacity, cyclic voltammetry, advanced glycation endproducts, anti-glycation
Abbreviations: AC, antioxidative capacity; **AGEs**, advanced glycation endproducts; **BSA**, bovine serum albumin; **CV**, cyclic voltammetry; **DPPH**, 2,2-diphenyl-1-picrylhydrazyl; **DPPH RSA**, DPPH radical scavenging activity; **TPC**, total phenolic contents

INTRODUCTION

Buckwheat is an alternative crop belonging, unlike cereals, to the *Polygonaceace* family. There are two types of buckwheat used around the world: common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tataricum* Gaertn). The common buckwheat is commonly grown, while a little of tartary buckwheat is grown in some mountainous regions. In Europe, tartary buckwheat is currently grown as a crop only in Luxemburg (Fabjan *et al.* 2003). Tartary buckwheat grain, as an important functional food material, contains proteins with a high biological value and balanced amino acid composition, relatively high crude fiber and vitamins B1, B2 and B6, and more rutin than the common buckwheat (Fabjan *et al.* 2003; Liu and Zhu 2007; Morishita *et al.* 2007). The presence of rutin in buckwheat is one of the main reasons for the production of different kinds of buckwheat foods (Kreft *et al.* 2006). No rutin was found in cereals and pseudocereals except for buckwheat, which can be used as a good source of dietary rutin (Park *et al*. 2000). Buckwheat-based products were found to have various biological activities, including increasing lactic acid bacteria in rat intestine, the efficacy of the treatment of allergic inflammation, reducing serum glucose level, suppressing cholesterol level, inhibiting protease and scavenging free radicals (Li and Zhang 2001; Kawa *et al*. 2003; Kim *et al.* 2003).

Buckwheat is an important material desired for tea preparation since the custom of drinking tea is very important worldwide from a viewpoint of dietary antioxidants (Ramaratham *et al.* 1995; Heck and De Mejia 2007). Currently, raw tartary buckwheat groats known as bitter buckwheat tea is available in healthy food stores in Europe. Also, a herbal tisane made from roasted buckwheat from the Yunnan province of China is a very popular herbal beverage in Southeast Asia and Japan, where it is known as *soba cha*, although some brands may be mixed with green tea.

Therefore, the aim of this study was to characterize the antioxidative and anti-glycation activities of bitter buckwheat tea and then compare them with those of green tea with mint - widely described in the last decade (Yen and Chen 1995; Chung *et al.* 1998; Lin *et al.* 1998; Kilmartin and Hsu 2003; Frejnagiel 2007).

MATERIALS AND METHODS

Chemicals

Acetonitrile and methanol (HPLC-grade) were provided by Merck (Darmstad, Germany). Sodium azide, bovine serum albumin (BSA), D-glucose, quercetin, rutin (quercetin-3-rutinoside), 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were purchased from Sigma (Sigma-Aldrich Sp. z o.o., Poznań, Poland). Orientin (3',4',5,7-tetrahydroxyflavone-8-glucoside), homoorientin (3',4',5,7-tetrahydroxy-flavone-6-glucoside), vitexin (4',5,7-trihydroxyflavone-8-glucoside) and isovitexin (4',5,7-trihydroxyflavone-8-glucoside) standards (HPLC-grade) were obtained from Extrasynthese Company Inc. (Lyon, France). All other reagents of reagent-grade quality were from POCH – Polish Chemical Compounds, Gliwice, Poland. Water was purified with a Milli-Q-system (Milipore, Bedford, USA). All solutions prepared for HPLC were passed through a 0.45 μm nylon filter before use.

Received: 12 March, 2009. Accepted: 25 April, 2009.

Original Research Paper

Materials

Bags of bitter buckwheat tea and green tea with mint were purchased from a healthy food store in Olsztyn, Poland. The bitter buckwheat tea originated from the Yunnan province of China and was made from unhusked tartary buckwheat, while the green tea with mint was produced by R. Twinning & Co Ltd., London (England).

Characterization of the material for tea preparation

In order to characterize the antioxidative properties of the material desired for tea preparation, an extraction with 80% methanol (MeOH) was carried out. The dry unhusked tartary buckwheat and green tea with mint leaves (2 g of each) were milled in a laboratory mill and then extracted in triplicate with 200 mL of 80% MeOH by shaking at 37°C for 2 h. Next, they were centrifuged at 12,000 × g in a Beckman GS-15 R centrifuge (Beckman Instruments, Inc., Palo Alto, CL, USA). The samples were concentrated up to 20 mL using a rotary evaporator at 45°C and then were directly used to determine total phenolic contents, flavonoids profile, antioxidative capacity by the cyclic voltammetry (CV) assay and the ability to scavenge DPPH radicals.

Preparation of bitter buckwheat tea and green tea with mint

Infusion from the unhusked tartary buckwheat and green tea with mint leaves were prepared according to the method described by Yen and Chen (1995). In brief, material desired for tea preparations (2 g of each), previously milled in a laboratory mill, was mixed with boiled water (200 mL), steeped for 10 minutes, and then the teas were filtrated through cellulose paper filter (Whatman No. 40). Thus prepared teas, referred to as ready-to-drink teas, were prepared in triplicate and afterwards subjected to BSA-glucose system to study the inhibitory effect on the formation of AGEs. The ready-to-drink teas were concentrated up to 20 mL using a rotary evaporator at 45°C and then used to determine total phenolic contents, flavonoids profile, antioxidative capacity by the CV assay and the ability to scavenge DPPH radicals.

Determination of total phenolic contents in dry material for tea preparation and teas

The content of total phenolic compounds was determined according to Shahidi and Naczk (1995). Exactly 0.25 mL of the concentrated 80% MeOH extract or respective tea was mixed with 0.25 mL of Folin-Ciocalteu's reagent (previously diluted with water 1:1 v/v) and 0.5 mL of a saturated sodium carbonate (Na_2CO_3) solution and 3 mL of water. The mixture was left to stand at room temperature for 25 min and then was centrifuged at 2000 × *g* for 10 min. Supernatant absorbance was measured at 725 nm using a spectrophotometer (UV-160 1PC, Shimadzu, Kyoto, Japan). Data were calculated as (±) catechin equivalents.

Flavonoids profile in the unhusked tartary buckwheat and in bitter buckwheat tea

The concentrated 80% MeOH extract from the unhusked tartary buckwheat and concentrated bitter buckwheat tea were subjected to flavonoids analysis with the use of an HPLC system (Shimadzu, Kyoto, Japan), consisting of two pumps (LC-10 AD), UV detector (SPD-10A) set at 330 nm, autosampler set to 20 µL injection (SIL-10 AD_{VP}), column oven (CTO-10 AS_{VP}) and system controller (SIL-10 AD_{VP}). All chromatographic determinations were performed at 35°C with the flow rate of 0.8 mL/min on C18(2) Luna 5 µm column, 4.6 × 200 mm (Phenomenex, Torrance, CA, USA). The flavonoids were eluted in a gradient system composed of 4% aqueous formic acid (solvent A) and acetonitrile containing 4% formic acid (solvent B). Gradients were as follows: 12-22-70-12-12% B at gradient time t_G=0-9-22-40-45-50 min. Rutin, quercetin, orientin, homoorientin, vitexin and isovitexin stock solutions were prepared in methanol at the concentrations of 500, 500, 517, 477, 509 and 574 µM, taking into account the purity of the standards. For quantitative analysis, calibration standards were prepared in duplicate at five concentrations within the range of 0.1-40 µM of each compound. All data are the average of triplicate analyses.

Determination of the antioxidative capacity of the dry material for tea preparation and teas by cyclic voltammetry (CV) assay

A potentiostat/galvanostat KSP system (Poland) was used for voltammetric experiments as reported recently in Zielinska *et al.* (2007). CV experiments were performed on concentrated 80% MeOH extracts of the unhusked tartary buckwheat and green tea with mint leaves and on the respective concentrated teas mixed with 0.2 M sodium acetate-acetic buffer (pH 4.5) at a ratio of 1:1 (v/v) in 80% MeOH or water, according to Cosio *et al*. (2006). The voltammetric experiments were performed at room temperature using an apparatus cell (volume 200 µL), to which concentrated 80% MeOH extracts or respective concentrated tea mixed with the buffer solution were introduced. Exactly 100 µL of each extract and 100 µL of buffer solution were used in assays. The cyclic voltammograms were acquired in the range of -100 to +1300 mV at a scanning rate of 100 mV s^{-1} at 2 mV intervals. For the test purpose, the total charge was measured below the anodic wave curve of the voltammogram. The CV method is actually based on the correlation between the total charge below anodic wave of cyclic voltammograms and the antioxidative capacity of the sample and reference substance. The 80% methanol and water solutions of Trolox within the concentration range of 0.025-1.25 mM were used and the results were expressed as µmol Trolox/g dry matter. The total charge under the anodic wave of the background signal (solvent + supporting electrode) was subtracted from the total charge under the anodic wave obtained for each sample measured within the range of +100 to +1100 mV. Triplicate samples were run for each set.

Determination of DPPH radical scavenging activity of the dry material for tea preparation and teas (DPPH RSA)

$DPPH^{\bullet}$ scavenging activity was determined using concentrated 80% MeOH extracts or concentrated teas as it was described previously by Zielinska *et al.* (2007). The 80% MeOH or water Trolox standard solutions (concentration range of 0.1-2.0 mM) were assayed under the same conditions and then $DPPH^{\bullet}$ scavenging activity of the samples was expressed in terms of Trolox equivalent antioxidant capacity on the basis of reduction in the absorbance of the $DPPH^{\bullet}$ solution by standards/samples at 515 nm. Measurements were carried out using a spectrophotometer (UV-160 1PC, Shimadzu, Kyoto, Japan). All data are the average of triplicate analyses.

BSA-glucose assay

This assay was based on an *in vitro* model for comparing the antiglycation activities of bitter buckwheat tea with those of green tea with mint (Rahbar *et al*. 2000; Wu and Yen 2005). In brief, 5 g of BSA and 14.4 g of D-glucose were dissolved in phosphate buffer (1.5 M, pH 7.4) to obtain the control solution with 50 mg/mL of BSA and 0.8 M D-glucose. The control solution (2 mL) was incubated at 37°C for 7 days in the presence or absence of 1 mL of bitter buckwheat tea or green tea with mint. The test solution contained also 0.2 g/L NaN_3 to assure aseptic conditions. After 7 days of incubation, fluorescent intensity (excitation, 330 nm; emission, 410 nm) was measured for the test solutions using a Perkin-Elmer LS 50 B Luminescence Spectrometer. Percent inhibition of AGE formation by each tea was calculated using the following equation:

$$\%\,\text{inhibition} = \left\{1 - \left(\frac{\text{fluorescence of the solution with tea}}{\text{fluorescence of the solution without tea}}\right)\right\} \times 100\%$$

Statistical analysis

The results are given as mean values and standard deviation of three independent experiments. Data were subjected to one-way analysis of variance (ANOVA) at a significance level of $p<0.05$ with Statistica 7.1.30.0 software (Statsoft Inc., USA) for Windows

Table 1 DPPH radical scavenging activity (DPPH RSA), antioxidative capacity (AC) determined with the cyclic voltammetry assay and total phenolic contents (TPC) of dry matter desired for tea preparations[1].

Sample	DPPH RSA (µmol Trolox/g d.m.)	TPC (mg catechin/g d.m.)	Total charge below anodic wave (µC)	AC (µmol Trolox/g d.m.)
Unhusked tartary buckwheat	177.28 ± 0.89 a	47.18 ± 0.71 a	161.69 ± 1.37 a	27.41 ± 0.54 a
Green tea leaves with mint	806.12 ± 7.61 b	127.46 ± 0.66 b	553.79 ± 1.01 b	96.13 ± 0.18 b

[1] Characterization of the unhusked tartary buckwheat and green tea leaves with mint was carried out after extraction by 80% MeOH. Data expressed as mean ± standard deviation (n = 3). Means in a column followed by the same letter are not significantly different ($p \leq 0.05$).

using a PC-Pentium.

RESULTS AND DISCUSSION

The total phenolic contents, flavonoids profile and antioxidative properties of the unhusked tartary buckwheat and green tea with mint leaves

In this study, unhusked tartary buckwheat desired for tea preparation was characterized by the total phenolic content and then compared to the green tea with mint leaves. For this reason, unhusked tartary buckwheat and green tea with mint leaves were milled and extracted with 80% methanol according to Oomah and Mazza (1996).

The content of 80% MeOH extractable phenolic compounds in unhusked tartary buckwheat (47.18 mg catechin equivalent/g dry matter) was approximately three-fold lower when compared to that of green with mint tea leaves (**Table 1**). The level of phenolic compounds in the unhusked tartary buckwheat was about 11 times higher in comparison to the unhusked common buckwheat as reported by Zielinski *et al.* (2006), whilst the high content of phenolics in commercial green tea with mint used as a reference one was consistent with results of the previous research in which the content of polyphenolic compounds and their glycosides was reported to reach up to 30% of dry matter, due to the high content of (-)-epicatechin (EC), (-)-epigallocatechin gallate (EGCG), (-)-epicatechin gallate (ECG) and (-)-epigallocatechin (EGC) (Balentine *et al.* 1997; Lin *et al.* 1998; Yao *et al*. 2006; Frejnagiel 2007).

Column chromatography on a C18 support allowed us to separate six flavonoid compounds. Rutin and quercetin contents were the highest and they constituted about 92 and 7.5% of all flavonoid content in buckwheat hulls, respectively (**Table 2**). The content of rutin in the unhusked tartary buckwheat was in agreement with that reported by Fabjan *et al.* (2003), who showed that rutin was the main active component of tartary buckwheat. Total content of other separated flavonoids included vitexin, isovitexin, orientin and homoorientin did not exceed 0.6%.

In this study, DPPH radical scavenging (DPPH RSA) of unhusked tartary buchwheat after extraction by 80% MeOH was 4.5-times lower then that of green tea with mint leaves extract (**Table 1**). The DPPH radical scavenging ability of polyphenolic compounds is mainly due to their hydrogen-donating ability. The extreme effectiveness of green tea extracts to scavenge superoxide, peroxynitrite, hydroxyl, 2,2-diphenyl-1-picrylhydrazyl radicals and ability to inhibit lipid peroxidation was reported during the last decade (Yen and Chen 1995; Chung *et al.* 1998; Lin *et al*. 1998; Frejnagiel 2007). The DPPH radical scavenging ability of green tea catechins is in the order of: EGCG > ECG > EGC > EC (Chen and Ho 1995), whilst that of tartary and common buckwheat are under investigation in our laboratories since

Table 2 Concentration of flavonoids in unhusked tartary buckwheat extracted by 80% MeOH and in a bitter buckwheat tea (µg/g dry matter) [1].

Compound	Extracted by 80% MeOH	After boiled water infusion [2]
Homoorientin	84.38 ± 0.42 a	110.68 ± 0.73 b
Orientin	59.14 ± 0.77 a	73.94 ± 0.78 b
Vitexin	45.86 ± 0.94 a	80.90 ± 1.07 b
Rutin	32855.29 ± 0.41 a	10178.90 ± 0.41 b
Isovitexin	36.50 ± 0.41 a	92.35 ± 0.30 b
Quercetin	2792.18 ± 1.94	nd
Total	35879.35 a	10536.77 b

[1] Means in a row followed by the same letter are not significantly different ($p \leq 0.05$).
[2] The results are equivalent to 100 mL of ready to drink bitter buckwheat tea.
nd: not detected

the antioxidant activity of individual compounds needs to be evaluated with different methods in which various free radicals are generated. The DPPH RSA values of unhusked tartary buckwheat and green tea with mint leaves showed a similar trend with those obtained with the CV assay. However, the antioxidative capacity of the unhusked tartary buckwheat and green tea with mint leaves determined by the CV method was approximately six and eight times lower than DPPH RSA (**Table 1**). This may indicate that the components of the unhusked tartary buckwheat and green tea leaves are mainly free radical scavengers, such as DPPH radicals, and that they were resistant, in part, to be oxidized on the surface of the glassy carbon electrode used in voltammetric experiments.

The total phenolics content, flavonoids profile and antioxidative properties of bitter buckwheat tea and green tea with mint

Herbal teas or tisanes are of increasing interest due to their reported high radical-scavenging activity and polyphenols content (Aoshima and Hirata 2007; Heck and De Mejia 2007). Therefore, in this study a conventional method of tea preparation was used.

The total phenolics content found in bitter buckwheat tea (10.20 mg catechin equivalent/g dry matter) was almost five times lower when compared to that of 80% methanol extract, whilst that found in green tea with mint was almost threefold lower (**Tables 1, 3**). These findings are in agreement with data reported by Pearson *et al.* (1998), who showed that a water extract of green tea contained about 45-52% of total polyphenols. However, it is possible to obtain a higher polyphenol concentration (up to 75% of total polyphenols) when use is made of specially laborious extraction (Baptista *et al*. 1999). The content of total phenolics in green tea with mint was 4.6- times higher than that noted in

Table 3 DPPH radical scavenging activity (DPPH RSA), antioxidative capacity (AC) determined with the cyclic voltammetry assay (CV) and total phenolic contents (TPC) of bitter buckwheat tea and green tea with mint[1].

Type of tea	DPPH RSA (µmol Trolox/g d.m.)	TPC (mg catechin/g d.m.)	Total charge below anodic wave (µC)	AC (µmol Trolox/g d.m.)
Bitter buckwheat tea	125.43 ± 0.63 a	10.20 ± 0.47 a	93.27 ± 2.01 a	11.93 ± 0.86 a
Green tea with mint	580.64 ± 29.16 b	47.34 ± 1.61 b	199.72 ± 7.09 b	36.93 ± 1.39 b

[1] The infusions were prepared by mixing 0.1 g of dry material with 10 mL of boiled water and therefore the results are equivalent to 100 mL of ready-to-drin teas. Data is expressed as mean ± standard deviation (n = 3). Means in a column followed by the same letter are not significantly different ($p \leq 0.05$).
d.m.: dry matter

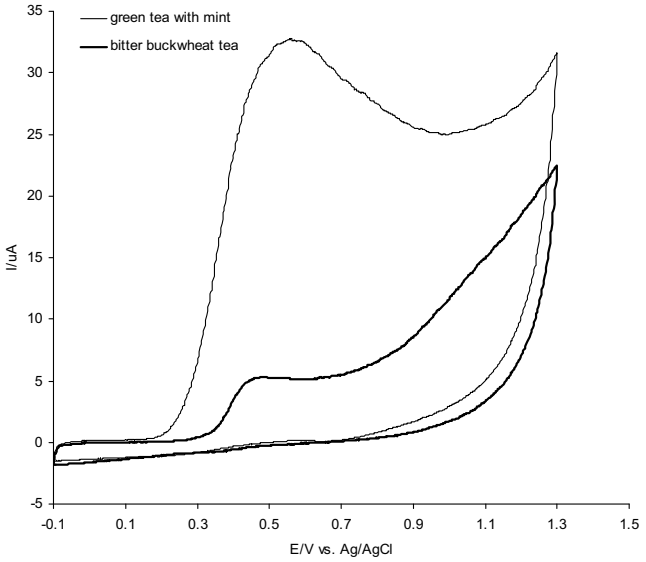

Fig. 1 Cyclic voltammograms of the analyzed teas. Operative conditions: concentration of each tea:100 mg/mL; sample preparation: boiled water infusion mixed with 0.2 M sodium acetate-acetic buffer (pH 4.5) at a ratio of 1:1 (v/v); scan rate 100 mV s^{-1}.

bitter buckwheat tea (**Table 3**).

The analysis of flavonoids in bitter buckwheat tea confirmed the presence of those found previously in 80% MeOH extract with one exception made to quercetin. The content of rutin was the highest and it formed 96.64% of all flavonoids (**Table 2**). These findings are extremely important since rutin and other flavonoids from buckwheat have many beneficial effects on human health. In the case of rutin, it was established that this compound antagonizes the increase of capillary fragility associated with hemorrhagic disease, reduces high blood pressure, decreases permeability of vessels and has an antiedema effects, and reduces the risk of arteriosclerosis (Fabjan *et al*. 2003). This study demonstrated that the boiled water extracted only 31% of rutin from the unhusked tartary buckwheat whilst a small increase in the content of flavone *C*-glucosides (homoorientin, orientin, vitexin and isovitexin) was observed. Quercetin was not detected in bitter buckwheat tea (**Table 2**), which was in accordance with its solubility rather in methanol than in water.

The DPPH RSA of bitter buckwheat tea (125.43 µmol Trolox/ g dry matter) was almost five times lower than that noted for green tea with mint (**Table 3**). Moreover, the DPPH RSA of bitter buckwheat tea (125.43 µmol Trolox/g dry matter) was 30% lower (**Table 3**) than that obtained after 80% methanol extraction (**Table 1**). Similarly, DPPH RSA of green tea with mint yielded 72% of radical scavenging activity obtained after extraction with 80% MeOH (**Tables 1, 3**). The values of DPPH RSA of bitter buckwheat tea and green tea with mint were significantly higher than the antioxidant capacity determined by CV. The CV tracing of bitter buckwheat tea and green tea with mint is shown in **Fig. 1**. In the case of bitter buckwheat tea, the observed anodic wave showed a broadened pick at 450 mV, while a similar one related to the green tea was observed at 600 mV. The antioxidative capacity of bitter buckwheat tea was about three-fold lower when compared to the antioxidative capacity of green tea with mint. On the other hand, the antioxidative capacity of bitter buckwheat tea and green tea with mint was 10 and 15 times lower when compared to DPPH RSA values, respectively (**Table 3**). This indicates that all antioxidants present in bitter buckwheat tea and green tea with mint were mainly free radical scavengers (Morishita *et al*. 2007).

Inhibitory effect of bitter buckwheat tea and green tea with mint on the formation of advanced glycation endproducts

The presence of rutin as the main component of bitter buckwheat tea, and small quantities of flavone *C*-glucosides, is extremely important in the prevention of human diseases. Various biological and pharmacological activities have been attributed to the flavone *C*-glucosides, such as anti-inflammatory, antispasmodic, antimicrobial, antioxidant/free radical scavenging, radioprotective effects and anti-glycation activities (Prabhakar *et al*. 1981; Hien *et al*. 2002; Lunceford and Gugliucci 2005). Recently, it has been suggested that advanced glycation endproducts (AGEs) accumulation has been implicated as a major pathogenic process in diabetes, atherosclerosis, Alzheimer's disease and normal aging (Ahmed 2005).

The BSA-glucose model adopted in this study provides a useful tool for assessing the effects of bitter buckwheat tea and green tea with mint on the non-enzymatic glycation process. **Fig. 2** shows the inhibitory effects of the bitter buckwheat tea and green tea with mint on AGE formation in this model. Ready-to-drink bitter buckwheat tea has shown 68.4% inhibition of the formation of AGEs, however that noted for green tea with mint reached 98.2%. The presence of rutin – one of the most potent natural AGE inhibitors – is suggested to be responsible for the anti-glycation activity of bitter buckwheat tea observed in this study. Taking into account the result of anti-glycation activity of bitter buckwheat tea, it may be speculated that their anti-glycation activities are mainly due to their radical scavenging capacity (Peng *et al*. 2008). Moreover, various phenolic antioxidants from plant extracts have been found to inhibit the formation of AGEs, and their inhibition of free radical generation in the glycation process has been considered as the major mechanism of mediation of their anti-glycation activities (Peng *et al*. 2008). Therefore, it may be speculated that the presence of mainly rutin and, to a small extent, of flavone *C*-glucosides, has largely contributed to the anti-glycation activity of bitter buckwheat tea due to their free radical scavenging and/or electroactive properties.

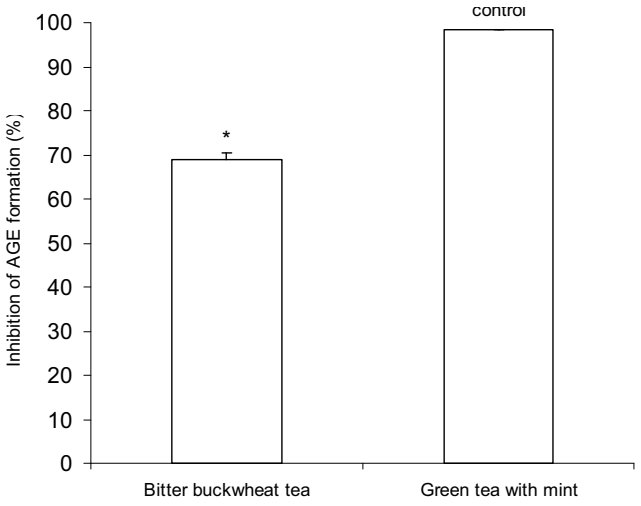

Fig. 2 Inhibitory effects of ready-to-drink bitter buckwheat tea and green tea with mint on the formation of AGEs in BSA-glucose model. The concentration of each tea is 1g/100 mL. Results are means ± SD for n = 3. Fluorescent intensities of the solutions with addition of teas were significantly different from that of the control solution ($P < 0.01$).

CONCLUSIONS

Data provided in this study may be important for tisane producers as well as for pharmaceutical and cosmetic industry. The bitter buckwheat tea showed lower antioxidative capacity determined with the DPPH RSA and CV assays and a

lower content of total phenolic compounds than the green tea with mint. The bitter buckwheat tea contained mainly rutin and a small quantity of flavonoids (quercetin and flavone *C*-glucosides) important from the dietary point of view. Therefore, the unhusked tartary buckwheat may be used for tea preparation as the main single tea ingredient or as a mixed component of other tisanes.

REFERENCES

Ahmed N (2005) Advanced glycation endproducts – role in pathology of diabetic complications. *Diabetes Research in Clinical Progress* **67**, 3-21

Aoshima H, Hirata S (2007) Antioxidative and anti-hydrogen peroxide activities of various herbal teas. *Food Chemistry* **103**, 617-622

Balentine DA, Wiseman SA, Bouwens LCM (1997) The chemistry of tea flavonoids. *Critical Review in Food and Nutrition* **37**, 693-704

Baptista JAB, Tavares JF, Carvalho RCB (1999) Comparative study and partial characterization of Azorean green tea polyphenols. *Journal of Food Composition and Analysis* **12**, 273-287

Chen CW, Ho CT (1995) Antioxidant properties of polyphenols extracted from green and black teas. *Journal of Food Lipids* **2**, 35-46

Chung HY, Yokozawa T, Soung DY, Kye IS, No JK, Baek BS (1998) Peroxynitrite-scavenging activity of green tea tannin. *Journal of Agricultural and Food Chemistry* **46**, 4484-4486

Cosio MS, Buratti S, Mannino S, Benedetti S (2006) Use of an electrochemical method to evaluate the antioxidant activity of herb extracts from the Labiatae family. *Food Chemistry* **97**, 725-731

Fabjan N, Rode J, Kosir IJ, Wang ZH, Zhang Z, Kreft AI (2003) Tartary buckwheat (*Fagopyrum tataricum* Gaertn.) as a source of dietary rutin and quercitrin. *Journal of Agricultural and Food Chemistry* **51**, 6452-6455

Frejnagiel S (2007) Comparison of polyphenolic composition of extracts from honeysuckle, chokeberries and green tea – a short report. *Polish Journal of Food and Nutrition Sciences* **57**, 83-86

Heck CI, De Mejia EG (2007) Yerba mate tea (*Ilex paraquariensis*): A comprehensive review in chemistry, health implications and technological considerations. *Journal of Food Science* **72**, R138-R151

Hien TV, Huong NB, Hung PM, Duc NB (2002) Radioprotective effects of vitexin for breast cancer patients undergoing radiotherapy with cobalt-60. *Integral Cancer Therapy* **1**, 38-34

Kawa JM, Taylor CG, Przybylski R (2003) Buckwheat concentrate reduces serum glucose in streptozotocin-diabetic rats. *Journal of Agricultural and Food Chemistry* **51**, 7287-7291

Kilmartin PA, Hsu CF (2003) Characterisation of polyphenols in green, oolong, and black teas, and in coffee, using cyclic voltammetry. *Food Chemistry* **82**, 501-512

Kim CD, Lee WK, No KO, Park SK, Lee MH, Lim SR (2003) Anti-allergic action of buckwheat (*Fagopyrum esculentum* Moench) grain extract. *International Immunopharmacology* **3**, 129-136

Kreft I, Fabjan N, Yasumoto K (2006) Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. *Food Chemistry* **98**, 508-512

Li S, Zhang OH (2001) Advance in the development of functional foods from buckwheat. *Critical Reviews in Food Science and Nutrition* **41**, 451-464

Lin Y-L, Cheng C-Y, Lin Y-P, Lau Y-W, Juan I-M, Lin J-K (1998) Hypolipidemic effect of green tea leaves through induction of antioxidant and phase II enzymes including superoxide dismutase, catalase, and glutathione *S*-transferase in rats. *Journal of Agricultural and Food Chemistry* **46**, 1893-1899

Liu B, Zhu Y (2007) Extraction of flavonoids from flavonoid-rich parts in tartary buckwheat and identification of the main flavonoids. *Journal of Food Engineering* **78**, 584-587

Lunceford N, Gugliucci A (2005) *Ilex paraguariensis* extracts inhibit AGE formation more efficiently than green tea. *Fitoterapia* **76**, 419-427

Morishita T, Yamaguchi H, Degi K (2007) The contribution of polyphenols to antioxidative activity in common buckwheat and tartary buckwheat grain. *Plant Production Science* **10 (1)**, 99-104

Oomah BD, Mazza G (1996) Flavonoids and antioxidative activities in buckwheat. *Journal of Agricultural and Food Chemistry* **44**, 1746-1750

Park CH, Kim YB, Choi YS, Heo K, Kim SL, Lee KC (2000) Rutin content in food products processed from groats, leaves and flowers of buckwheat. *Fagopyrum* **17**, 63-66

Pearson DA, Frankel EN, Aeschbach R, German JB (1998) Inhibition of endothelial cell mediated low-density lipoproteins oxidation by green tea extracts. *Journal of Agricultural and Food Chemistry* **46**, 1445-1449

Peng X, Zheng Z, Cheng K-W, Shan F, Ren G-X, Chen F, Wang M (2008) Inhibitory effect of mung bean extract and its constituents vitexin and isovitexin on the formation of advanced glycation endproducts. *Food Chemistry* **106**, 475-481

Prabhakar MC, Bamo H, Kumar I, Shamsi MA, Khan SY (1981) Pharmacological investigations on vitexin. *Planta Medica* **43**, 396-403

Rahbar S, Yerneni KK, Scott S, Gonzales N, Lalezari I (2000) Novel inhibitors of advanced glycation endproducts (part II). *Molecular Cell Biology Research Communications* **3**, 360-366

Ramaratham N, Osawa T, Ochi H, Kawakishi S (1995) The contribution of plant food antioxidants to human health. *Trends in Food Science and Technology* **61**, 75-82

Shahidi F, Naczk M (1995) Methods of analysis and quantification of phenolic compounds. In: Shahidi F, Naczk M (Eds) *Food Phenolics: Sources, Chemistry, Effects and Applications*, Technomic Publishing Co., Lancaster/ Pennsylvania, pp 287-293

Wu CH, Yen GC (2005) Inhibitory effect of naturally occurring flavonoids on the formation of advanced glycation endproducts. *Journal of Agricultural and Food Chemistry* **53**, 3167-3173

Yao LH, Jiang YM, Caffin N, D'Arcy B, Data N, Liu X, Singanusong R, Xu Y (2006) Phenolic compounds in tea from Australian supermarkets. *Food Chemistry* **96**, 614-620

Yen G-C, Chen H-Y (1995) Antioxidant activity of various tea extracts in relation to their antimutagenicity. *Journal of Agricultural and Food Chemistry* **43**, 27-32

Zielińska D, Szawara-Nowak D, Ornatowska A, Wiczkowski W (2007) The use of cyclic voltammetry, photochemiluminescence and spectrophotometric methods for the measurement of the antioxidant capacity of buckwheat sprouts. *Journal of Agricultural and Food Chemistry* **55**, 9891-9898

Zieliński H, Michalska A, Piskuła MK, Kozłowska H (2006) Antioxidants in thermally treated buckwheat groats. *Molecular Nutrition and Food Research* **50**, 824-832